

INTERNAL COMBUSTION ENGINE WITH EXHAUST TREATMENT SYSTEM

[0001] Prior Art

[0002] The invention relates first to an internal combustion engine, in particular equipped with fuel direct injection, having an exhaust treatment system for reducing pollutants in the exhaust, which includes: a reservoir containing a fluid active ingredient, a delivery device for delivering the active ingredient, and an injection device for injecting the active ingredient into the exhaust.

[0003] There is a need for reducing nitrogen oxide emissions from motor vehicles, particularly in light of legal requirements expected in future. In order to reduce nitrogen oxide emissions from internal combustion engines, for example those with gasoline or diesel direct injection, so-called selective catalytic reduction (SCR) can be used. This process introduces a definite quantity of a reducing agent, in particular urea, into an exhaust line. Since urea is solid under normal environmental conditions, it is supplied in the form of a urea/water solution that is injected into the exhaust. In a first reaction stage, the urea reacts with water to produce ammonia and carbon dioxide. In a second reaction stage, the ammonia reduces the nitrogen oxides contained in the exhaust to nitrogen, with water produced as a byproduct.

[0004] DE 101 39 142 A1 has disclosed an exhaust treatment system for an internal combustion engine in which a pump supplies a urea/water solution from a reservoir to a

mixing chamber in which compressed air is used to produce an aerosol that is then injected into the exhaust of the internal combustion engine.

[0005] The object of the present invention is to improve the efficiency of the exhaust treatment.

[0006] This object is attained in an internal combustion engine of the kind mentioned at the beginning in that the exhaust treatment system has a pressure reservoir into which the delivery device feeds; this pressure reservoir is able to store the active ingredient under pressure and is directly connected to the injection device.

[0007] Advantages of the Invention

[0008] A first advantage of the internal combustion engine according to the present invention is that because of the elevated pressure in the pressure reservoir, which is then in principle also present in the injection device, the injection device is able to atomize the active ingredient particularly well, thus imparting a good preparation quality to the resulting spray. This leads to an improved conversion rate of the active ingredient in the exhaust. The temporary storage of the active ingredient in the pressure reservoir also permits the optional use of a delivery device with a lower delivery capacity since “consumption peaks” in a corresponding system configuration can be covered not by an increased delivery capacity but by the active ingredient temporarily stored in the pressure reservoir.

[0009] Advantageous modifications of the present invention are disclosed in the dependent claims.

[0010] In a first embodiment, the delivery device includes a presupply pump and a high-pressure pump. The presupply pump can, for example, be a diaphragm pump and the high-pressure pump can be a piston pump. This makes it possible to achieve particularly high pressures in the pressure reservoir, which in turn results in a particularly good atomization of the active ingredient during injection into the exhaust.

[0011] It is also advantageous if the pressure reservoir is connected to a pressure regulating device. This either permits a high degree of pressure constancy or, with an adjustable pressure regulating device, enables the pressure in the pressure reservoir to be varied, which permits an optimal adaptation of the pressure the pressure reservoir to the current operating state of the exhaust treatment system and/or the internal combustion engine.

[0012] A particularly advantageous embodiment of the internal combustion engine according to present invention has a control and/or regulating unit that controls and/or regulates the delivery capacity of the delivery device, the pressure in the pressure reservoir, the time at which the injection of the active ingredient occurs, and/or the duration of the injection of the active ingredient as a function of the operating state of the internal combustion engine. This permits a particularly economical consumption of the active ingredient with a simultaneously optimal conversion rate of the active ingredient in the exhaust.

[0013] The costs for the internal combustion engine according to present invention can be reduced if the delivery device, the pressure reservoir, and/or the injection device are of the type used in direct-injecting fuel systems. In particular, these include the fuel systems that operate with a fuel accumulator (“common rail”). It may be necessary to select those systems whose delivery devices are not lubricated by the fluid delivered.

[0014] Another embodiment is distinguished by the fact that the active ingredient is urea. In general, the urea here is bound in an aqueous solution and is not dangerous, but permits an effective reduction of nitrogen oxides in the exhaust.

[0015] In a modified embodiment, it is possible to heat the pressure reservoir. The urea/water solution usually used has the property of freezing, i.e. changing from the fluid to the solid state, at temperatures below -11°C . The ability to heat the pressure reservoir assures the functionality of the exhaust treatment system even at such low temperatures.

[0016] The present invention also relates to a method for operating an internal combustion engine of the type mentioned above. The delivery capacity of the delivery device, the pressure in the pressure reservoir, the time at which the injection of the active ingredient occurs, and/or the duration of the injection of the active ingredient depend on the current operating state of the internal combustion engine. This permits a particularly effective reduction in pollutant emissions in the exhaust with a simultaneously low consumption of the active ingredient.

[0017] In a modified embodiment, the operating parameters include a speed of a crankshaft, a torque of the engine, a fuel mass injected into a combustion chamber, a temperature of the engine, a temperature of the ambient air, a humidity of the ambient air, a temperature before and/or after a catalytic converter, an NO_x and/or NH₃ content in the exhaust, and/or a fuel/air ratio in the combustion chamber, or an equivalent value. In many internal combustion engines, these operating parameters are detected anyway so that no additional sensors are required in order to use them, which reduces the costs of the engine. Primarily, the use of an NO_x or NH₃ content in the exhaust permits a regulated metering of the active ingredient and possibly even an adaptation of the models used for the metering.

[0018] The corresponding control and/or regulation algorithms have usually already been worked out since the input and output values required for calculating the metered quantities are used in a similar form in the context of fuel direct injection and are thus already on hand. It is also conceivable that the calculation and application of the data required for the injection or metering of the active ingredient can be determined based on characteristic maps of the internal combustion engine. This could save on the cost of an additional control unit and certain quantity corrections could be carried out in parallel based on corresponding correction coefficients that are calculated as part of the process of controlling the engine.

[0019] Drawings

[0020] A particularly preferred exemplary embodiment of the present invention will be explained in detail below in conjunction with the accompanying drawings.

[0021] Fig. 1 shows a schematic diagram of an internal combustion engine with an exhaust treatment system; and

[0022] Fig. 2 shows the input and output values for controlling and regulating the exhaust treatment system from Fig. 1.

[0023] Description of the Exemplary Embodiment

[0024] In Fig. 1, an internal combustion engine is labeled as a whole with the reference numeral 10. It has a number of combustion chambers, only one of which – labeled with the reference numeral 12 – is shown in Fig. 1 for the sake of clarity. Combustion air travels into the combustion chamber 12 via an inlet valve 14 and an intake tube 16. Sensors 15 and 17 detect a temperature TASP and a humidity HASP of the aspirated ambient air. The hot combustion gases are conveyed out of the combustion chamber 12 via an outlet valve 18 and an outlet tube 20. During operation, a crankshaft 21 is set into rotation. A fuel injection device 22 delivers fuel directly into the combustion chamber 12.

[0025] The injected fuel in the current exemplary embodiment is diesel fuel. The fuel injection device 22 is connected to a fuel accumulator 24 (“rail”). The fuel is stored at high pressure in this rail. A presupply pump 28 delivers fuel from a fuel tank 30 to a high-pressure fuel pump 26, which then delivers it to the fuel accumulator 24. A sensor 32 detects the pressure in the fuel accumulator 24 and a pressure regulator 34 adjusts this pressure. A

quantity control valve 36 adjusts the delivery quantity of the high-pressure fuel pump 26. The above-mentioned components 22 through 36 are part of a fuel system 37.

[0026] The internal combustion engine 10 is equipped with an exhaust treatment system 38 in order to reduce pollutant emissions in its exhaust. This system includes an oxidation converter 39, which is situated in the exhaust line 20 and converts NO into NO₂, and a catalytic converter 40 that then reduces pollutants in the exhaust. Upstream of the catalytic converter 40, the exhaust line 20 contains a temperature sensor 41 for detecting the temperature TSCR of the exhaust and an injection device 42 that is able to inject an active ingredient, urea 43 in the present exemplary embodiment, into the exhaust flowing through the exhaust line 20. To this end, the urea is dissolved in water, i.e. the final step is the injection of a urea/water solution. Downstream of the catalytic converter 40, there is a lambda probe 45 and an NO_x sensor 47.

[0027] The urea/water solution 43 is stored in a urea receptacle 44. A presupply pump 46 feeds the urea/water solution 43 from the urea receptacle 44 to a high-pressure pump 48 (the two pumps 46 and 48 together constitute a delivery device 49). This device compresses the urea/water solution 43 to a very high pressure and delivers it to a urea pressure reservoir 50, which can be tubular or spherical, for example, and is in turn connected to the injection device 42.

[0028] A pressure sensor 52 detects the pressure in the urea pressure reservoir 50. A pressure regulator 54 adjusts the pressure in the pressure reservoir 50 and a quantity control

valve 56 adjusts the delivery quantity of the high-pressure urea pump 48. All the components of the exhaust treatment system 38 except for the catalytic converter 40 and the injection device 42 can be heated by an electrical heating unit 58.

[0029] A control and/or regulating unit 60 controls and/or regulates the operation of the internal combustion engine 10, including the operation of the fuel system 37. It receives signals from numerous sensors, for example the two pressure sensors 32 and 52, as well as from additional sensors not shown in Fig. 1, and controls the corresponding adjusting and regulating devices, for example the injection devices 22 and 42, the quantity control valves 36 and 56, and the pressure regulators 34 and 54, as a result of which the internal combustion engine 10 generates a desired output with the lowest possible fuel consumption and an optimal emissions behavior. The control and regulating unit 60 also controls and/or regulates the operation of the exhaust treatment system 38.

[0030] As is clear from Fig. 2, various input values are fed into a processing block 62. These include a speed N of the crankshaft 21, a relative air charge RA in the combustion chamber 12, a relative fuel mass RF injected into the combustion chamber 12 by the fuel injection device 22, a temperature $TMOT$ of the engine 10 (e.g. a cooling water temperature or a cylinder head temperature), and the fuel/air ratio in the combustion chamber 12, which is represented by the air number $LAMBDA$. Other values can include a temperature $TSCR$ of the catalytic converter 40, a relative humidity $HASP$ of the aspirated air, for example a temperature $TASP$ of the ambient air, or an NO_x value.

[0031] Based on these values, control variables required for operating the exhaust treatment system 38 are determined in the processing block 62. These include a pressure PR_UPR in the urea pressure reservoir 50, a triggering voltage U_UPR for the quantity control valve 56, which in turn adjusts a delivery quantity M_UPR for the delivery device 49, an injection duration TI_UPR of the injection device 42 for the urea 43, and a bit B_HEAT that turns the heating unit 58 on and off.

[0032] Is clear that in the internal combustion engine 10, the operation of the exhaust treatment system 38 is essentially controlled by means of operating values of the engine 10. The pressure PR_UPR in the urea pressure reservoir 50 and the injection duration TI_UPR of the urea injection device 42 can be used to adapt the injected quantity on the one hand and the degree of atomization of the urea/water solution 43 on the other to the current operating requirements of the internal combustion engine 10. On the one hand, this assures an optimal conversion of the injected urea/water solution 43, which leads to a reduction in pollutant emissions, and on the other, the urea/water solution 43 can be used very economically since it is possible to avoid generating too much ammonia, but at the same time to assure an almost 100% conversion rate.

[0033] Similar to the fuel system 37, the pressure in the urea pressure reservoir 50 can be very high and can lie in the range above 50 bar, if need be even in a range from a few hundred bar to over a thousand bar. The components used for the exhaust treatment system 38 can be similar to the components of the fuel system 37. It is also possible, at least in some regions, to use components identical to those of the fuel system 37. In addition, the processing model

used in the processing block 62 can resemble or even be identical to the one used to control and/or regulate the fuel system 37. In the processing block 62, usually the pressure PR_UPR depends primarily on the speed N of the crankshaft 21 and on the temperature TSCR of the exhaust. At a constant speed, the pressure regulator 54 and the quantity control valve 56 can be used to set a constant pressure in the urea pressure reservoir 50.

[0034] In the exemplary embodiment depicted in Fig. 1, the urea injection device 42 injects the urea/water solution 43 directly into the exhaust line 20. However, it is also possible for air to be fed into the urea injection device 42 and for this air to be mixed with the urea/water solution 43 either inside the urea injection device 42 or upon exiting from it.

[0035] In the present exemplary embodiment, the active ingredient is referred to as urea 43. Naturally, however, the above-described embodiment of the exhaust treatment system 38 can use any other substance as the active ingredient, as long as this substance can be injected into the exhaust. For example, this could include the injection of diesel fuel, or in the most general sense, HC, or also the injection of gaseous or powdered substances.

[0036] It should also be noted that in the context of the preceding specification, different components have been referred to for short as merely “urea” components (e.g. the “urea pressure reservoir”) despite the fact that in the exemplary embodiment described above, pure urea was naturally not used but instead always a urea/water solution.